Tillage Systems for Wheat Production in the Southeastern Coastal Plains[1]

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ABSTRACT

Increased wheat (*Triticum aestivum* L.) production has raised numerous questions regarding tillage practices and N fertilizer rates for the Coastal Plain. Therefore, eight field studies conducted on Ardilla (Fragiaquic Paleudults), Dothan (Plinthic Paleudults), and Norfolk (Typic Paleudults) soils are summarized to report N fertilizer and tillage effects. Average grain yield with moldboard plowing was significantly higher (0.4 Mg ha^{-1}) than with disking in four of five studies, but it was significantly higher than chisel plowing (3.09 vs. 2.48 Mg ha^{-1}) only once. No-till yield was significantly lower (0.5 Mg ha^{-1}) than yield with disking in two of four studies. Nitrogen response was significant in five of six studies, but the tillage × N interaction was significant only once. Head number and weight were increased by plowing or higher N rates. Poor soil-seed contact presumably caused erratic stands and lower no-till yields because seedling emergence was not reduced by the equivalent of 10 Mg ha^{-1} of corn (*Zea mays* L.) residue. Approximately 100 kg N ha^{-1} was sufficient for conventional tillage, but chisel or moldboard plowing should be used rather than disking. For no-till wheat, drills must provide good soil-seed contact and N rates may have to be increased.

Additional index words: Triticum aestivum L., No-tillage, Chisel plow, Moldboard plow, Nitrogen, Nitrogen rate.

Soft red winter wheat (*Triticum aestivum* L.) production has increased in the southeastern Coastal Plains because of economic pressures. For example, current crop budgets, prepared by the Clemson University Extension Service, show an increased profit of approximately \$143 ha^{-1} for double crop wheat and no-till soybean [*Glycine max* (L.) Merr.] as compared to full-season, no-till soybean. This increased profit potential has raised numerous questions about tillage systems and optimum N rates for wheat production in this region.

Tillage systems for soybean and corn (*Zea mays* L.) have been studied intensively in the southeastern Coastal Plains (4,5), but much less research has been done to evaluate tillage systems for wheat (16). Studies in Europe, the U.S. Great Plains, and the Pacific Northwest (1,2,6,9,11,20) have shown an advantage for no-till or direct drilling wheat because of soil and water conservation. However, on loamy sands in Australia (12) and clayey soils in the Appalachian Piedmont (13,19), use of moldboard plowing significantly increased wheat yields when compared to no-till production. This response may have occurred because restrictive layers were disrupted and better root development was allowed (17).

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Studying N fertilizer rates in conjunction with tillage systems is important because soil microbial populations in no-till and tilled soils are significantly different (10, p. 441–455). Those population differences are caused by changes in soil water content, residue distribution, and soil aeration, but more importantly, they significantly change N cycling when compared to conventional tillage practices. Another factor that must be evaluated as tillage systems are changed is cultivar selection. This has been done for corn (14) in the Coastal Plains, but not for wheat.

The objective of this research was to evaluate tillage systems and N fertilizer rates to provide answers to the many questions that were being raised by Coastal Plain farmers. This paper summarizes eight field experiments and identifies problems that need further research to improve wheat production in this region.

MATERIALS AND METHODS

Eight field studies were conducted on three different soil series at three locations in the South Carolina Coastal Plain during 1983, 1984, and 1985. The soil series were Ardilla loamy sand (fine-loamy, siliceous, thermic Fragiaquic Paleudults) near Blackville; Dothan loamy sand (fine-loamy, siliceous, thermic Plinthic Paleudults) near Sumter; and Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Paleudults) near Florence. A greenhouse experiment was also conducted using Norfolk loamy sand to evaluate the effects of surface-applied corn residue on seedling establishment and growth characteristics of four wheat cultivars.

Soil samples were collected to a depth of 200 mm (Ap horizon) before each study was conducted. Samples were analyzed for water pH and Mehlich I extractable P, K, Ca, Mg, Mn, and Zn using standardized procedures (8). Samples were not analyzed for NO_3–N because this is not a routine procedure for this area. Lime, P, and K were applied before imposing tillage and N treatments at rates based on soil-test results (Table 1) that consistently showed high P and Mg, medium K and Ca, and adequate Mn and Zn (7).

Study I was conducted in 1983 on Dothan loamy sand near Sumter. Tillage plots (8.2 m wide by 9.1 m long) were replicated four times and prepared by either disking 150 mm deep, chisel plowing 280 mm deep, or moldboard plowing 250 mm deep. All plots received 33-22-83 kg N-P-K ha^{-1} and were disked lightly (50 mm deep) prior to drilling 'Coker 797' wheat at a seeding rate of 100 kg ha^{-1} in rows 180 mm apart on 21 Dec. 1982. On 4 Mar. 1983, during Feekes (15) growth stage (FGS) 3.0, tillage plots were split into three subplots 2.7 m wide and topdressed with 30% N solution (UAN) at rates of 34, 57, or 79 kg N ha^{-1} so that total N rates for the year were either 67, 90, or 112 kg ha^{-1}, respectively. Winter weeds were controlled by applying 0.6 kg a.i. ha^{-1} of 2,4-D [2,4-dichlorophenoxy)acetic acid] on 25 March. Plant samples were collected on 11 April, during FGS 7.0, and analyzed for N and S concentrations using standard procedures at Clemson University's Soil and Plant Analysis Laboratory. On 16 June, three rows (5 m^2) from each plot were hand harvested, dried, thrashed, and adjusted to a constant water content of 130 g kg^{-1} to determine grain yield.

Study II was conducted in 1983 on Ardilla loamy sand near Blackville. Tillage plots (8.2 m wide by 9.1 m long) were replicated four times and prepared by either disking 150 mm deep, chisel plowing 280 mm deep, or moldboard plowing 250 mm deep. All plots received 33-22-83 kg N-P-K ha^{-1} and were disked lightly (50 mm deep) prior to drilling 'Coker 762' wheat at a seeding rate of 100 kg ha^{-1} in rows 180 mm apart on 12 Nov. 1982. On 21 Feb. 1983, during FGS 3.0, tillage plots were split into three subplots 2.7 m wide and topdressed with 30% UAN at rates of 34, 57, or 79 kg N ha^{-1} so that total N rates for the year were either 67, 90, or 112 kg ha^{-1}, respectively. Winter weeds were controlled by applying 0.6 kg a.i. ha^{-1} of 2,4-D on 14 March. On 9 June, three rows (5 m^2) from each plot were hand harvested, dried, thrashed, and adjusted to a constant water content of 130 g kg^{-1} to determine grain yield.

Study III was conducted in 1984 on Ardilla loamy sand near Blackville. Tillage plots (8.2 m wide by 9.1 m long) were replicated four times and prepared by either disking 150 mm deep, chisel plowing 280 mm deep, or moldboard plowing 250 mm deep. All plots received 33-18-69 kg N-P-K ha^{-1} and were disked lightly (50 mm deep) prior to drilling Coker 762 wheat at a seeding rate of 100 kg ha^{-1} in rows 180 mm apart on 14 Nov. 1983. On 20 Feb. 1984, during FGS 3.0, tillage plots were split into three subplots 2.7 m wide and topdressed with 30% UAN at rates of 57, 79, or 101 kg N ha^{-1} so that total N rates for the year were either 90, 112, or 134 kg ha^{-1}, respectively. Winter weeds were controlled by applying 0.4 kg a.i. ha^{-1} of 2,4-D on 12 March. On 10 June, three rows (5 m^2) from each plot were hand harvested, dried, thrashed, and adjusted to a constant water content of 130 g kg^{-1} to determine grain yield.

Study IV was conducted in 1985 on Ardilla loamy sand near Blackville. Tillage plots (8.2 m wide by 9.1 m long) were replicated four times and prepared by either disking 150 mm deep, chisel plowing 280 mm deep, or moldboard plowing 250 mm deep. All plots received 33-22-83 kg N ha^{-1} and were disked lightly (50 mm deep) prior to drilling 'Pioneer 2550' wheat at a seeding rate of 100 kg ha^{-1} in rows 180 mm apart on 15 Nov. 1984. On 21 Feb. 1984, during FGS 3.0, tillage plots were split into three subplots 2.7 m wide and topdressed with 30% UAN at rates of 57, 79, or 101 kg N ha^{-1} so that total N rates for the year were either 90, 112, or 134 kg ha^{-1}, respectively. Winter weeds were controlled by applying 0.4 kg a.i. ha^{-1} of Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) on 7 March. On 5 June, grain yield was measured with a plot combine by harvesting the center (11.2 m^2) of each plot. Grain moisture was measured and used to adjust plot weights to a constant water content of 130 g kg^{-1} before calculating yields. The number and weight of heads per unit area were determined by collecting 3 m of row (0.5 m^2) by hand immediately after harvest. Samples were dried at 65°C before counting and weighing the heads.

Study V was conducted in 1983 on Norfolk loamy sand at Clemson University's Pee Dee Research and Education Center near Florence. Irrigated and nonirrigated corn had been grown at the 2.8-ha site using disk tillage (DT) or conservation tillage (CT) to prepare the seedbed each year since 1979. After 4 yr of continuous corn, a rotation was established by planting one-half of the site to wheat. Following corn harvest in September 1982, stalks were shredded with a flail chopper and soil samples were collected from each of five replicates. No-till wheat was evaluated on 23-m-wide by 26-m-long CT plots where the surface soil had not been disked

Table 1. Soil type, chemical characteristics, and seasonal rainfall associated with eight wheat studies conducted in 1983, 1984, and 1985 in the South Carolina Coastal Plain.

Study	Year	Series	pH	P	K	Ca	Mg	Mn	Zn	Rainfall
				mg kg^{-1}						mm
I	1983	Dothan	6.1	50	46	260	26	--	--	883
II	1983	Ardilla	6.4	73	48	360	49	--	--	656
III	1984	Ardilla	6.0	87	48	550	50	19	1.9	964
IV	1985	Ardilla	6.0	104	48	480	46	--	--	364
V	1983	Norfolk	5.4	55	85	301	49	10	4.3	764
VI	1984	Norfolk	5.7	44	71	321	74	12	4.5	895
VII	1985	Norfolk	5.8	54	78	394	101	19	3.7	427
VIII	1985	Norfolk	5.6	67	57	268	65	6	2.6	408

since 1978. The plots were sprayed with paraquat (1,1′-dimethyl-4,4′-bipyridinium dichloride) at a rate of 0.3 kg a.i. ha^{-1} prior to applying 1.7 Mg ha^{-1} of dolomitic lime and 41-53-90 kg ha^{-1} of N-P-K, respectively. Similar size (23- by 26-m) DT plots were maintained where surface residues had been incorporated each year to evaluate DT for wheat production. Management practices for DT wheat were the same as for no-till, except that chopped stalks and weeds were incorporated by disking rather than spraying them with paraquat.

A KMC[3] no-till Uni-drill (Kelley Manufacturing Co., Tifton, GA) was used to plant Coker 797 wheat into both seedbeds at a seeding rate of 100 kg ha^{-1} in 180 mm rows on 22 Nov. 1982. On 10 Mar. 1983, during FGS 3.0, the wheat was topdressed with 66 kg N ha^{-1} using ammonium nitrate. Winter weeds were controlled by applying 0.5 kg a.i. ha^{-1} of 2,4-D on 13 March. Tensiometers were installed in the irrigated blocks at depths of 0.2, 0.4, and 0.9 m. A total of 90 mm of water was applied by irrigating when soil water tension at 0.2 m exceeded 0.25 MPa. A plot combine was used to harvest three 35-m^2 strips from each tillage and water management block on 15 June. Grain moisture was measured with a Steinlite[3] Model SS250 electronic moisture meter (Fred Stein Laboratories, Inc., Atchison, KS) and used to adjust plot yields to a constant water content of 130 g kg^{-1} before calculating yields.

Study VI was conducted in 1984 at the same site as that used in Study V, but on the half that had been planted to corn in 1983. Stalks were shredded, soil samples collected, and no-till plots sprayed with glyphosate [isopropylamine salt of N-(phosphonomethyl)glycine] at a rate of 1.7 kg a.i. ha^{-1} before applying 1.7 Mg ha^{-1} of dolomitic lime. The tillage plots were split into three strips and fertilized with 40 kg P ha^{-1} and 75 kg K ha^{-1} plus 34, 67, or 100 kg N ha^{-1}. The Uni-drill was used to plant Coker 797 wheat at a seeding rate of 100 kg ha^{-1} in 180 mm rows on 9 Nov. 1983. On 22 Feb. 1984, during FGS 3.0, the wheat was topdressed with ammonium nitrate. The 34 kg N ha^{-1} subplots were split and topdressed with either 34 or 67 kg N ha^{-1}. The 67 kg N ha^{-1} subplots were split and topdressed with either 67 or 134 kg N ha^{-1}. The 100 kg N ha^{-1} subplots were split and topdressed with 67 or 134 kg N ha^{-1}. This created six fall-spring N treatment combinations (34-34, 34-67, 67-67, 67-134, 100-67, and 100-134), which were imposed on the tillage and water management blocks in a stripped, split-split plot design. Winter weeds were controlled by applying 0.5 kg a.i. ha^{-1} of 2,4-D on 12 March. Tensiometers were installed in the irrigated blocks at depths of 0.2, 0.4, and 0.9 m. A total of 40 mm of water was applied by irrigating when soil water tension at 0.2 m exceeded 0.25 MPa. A plot combine was used to harvest one 35-m^2 strip from each N plot on 11 June. Grain moisture was measured and used to adjust plot yields to a constant water content of 130 g kg^{-1} before calculating yields. The number and weight of heads per unit area were determined by collecting 3.6 m of row (0.65 m^2) by hand immediately after harvest. Samples were dried at 65°C before counting and weighing the heads.

Study VII was conducted in 1985 on the same tillage plots that Study V was conducted on in 1983. Corn stalks were shredded, soil samples collected, and no-till plots sprayed with 1.1 kg a.i. ha^{-1} glyphosate plus 0.4 kg a.i. ha^{-1} Poast {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} before applying 1.1 Mg ha^{-1} of dolomitic lime. The tillage plots were split into three strips, fertilized with 14-28-10 kg P-K-S ha^{-1} plus 34, 67, or 100 kg N ha^{-1}, and planted with the Uni-drill to Coker 797 wheat at a seeding rate of 100 kg ha^{-1} in 180 mm rows on 27 Nov. 1984. On 4 Mar. 1985, during FGS 3.0, the wheat was topdressed with ammonium nitrate to repeat the same six N treatments as used in Study VI. Winter weeds were controlled by applying 0.3 kg a.i. ha^{-1} of 2,4-D on 13 March. Tensiometers were installed in the irrigated blocks at depths of 0.2, 0.4, and 0.9 m. A total of 140 mm of water was applied by irrigating when soil water tension at 0.2 m exceeded 0.25 MPa. A plot combine was used to harvest one 35-m^2 strip from each N plot on 13 June. Grain moisture was measured and used to adjust plot yields to a constant water content of 130 g kg^{-1} before calculating yields. The number and weight of heads per unit area were determined by collecting 6 m of row (1.0 m^2) by hand immediately after harvest. Samples were dried at 65°C before counting and weighing the heads.

Study VIII was conducted in 1985 on Norfolk loamy sand at the ARS Coastal Plains Research Center near Florence. Four tillage systems used for seedbed preparation (no-till, disking, chisel plow, and moldboard plow) and four wheat cultivars (Coker 916, Coker 983, Hybrex HW3021, and Hybrex HW3022) were evaluated in a nonirrigated study. Soil samples were collected and analyzed before dolomitic lime (1.1 Mg ha^{-1}) and 34-0-75-10 kg N-P-K-S ha^{-1} were broadcast. The tillage treatments were established on plots that were 14 m wide and 41 m long. On 21 November, those plots were split into four subplots, 3.5 m wide, that were planted with the four wheat cultivars at a seeding rate of 100 kg ha^{-1} in 180 mm rows using the Uni-drill. The wheat was topdressed during FGS 3.0 with 56 kg N ha^{-1} using 30% UAN on 1 Mar. 1985. Winter weeds were controlled by applying 0.3 kg a.i. ha^{-1} of 2,4-D on 11 March. The number and weight of heads per unit area were determined by collecting 6 m of row (1.0 m^2) by hand on 24 May. Samples were dried at 65°C before counting and weighing the heads. A plot combine was used to harvest the center 55 m^2 from each plot on 11 June. Grain moisture was measured and used to adjust plot yields to a constant water content of 130 g kg^{-1} before calculating yields.

The four wheat cultivars evaluated in Study VIII were also grown in a greenhouse experiment (Study IX) to determine the effects of three levels of corn residue on germination, seedling establishment, water use, and relative shoot and root growth. Standard No. 8 plastic pots were filled with 4.54 kg of sieved Norfolk loamy sand that was limed to raise the pH to 6.0, and fertilized with the equivalent of 270-41-136 kg ha^{-1} of N-P-K, respectively. Water was added to raise the water content to approximately 20 volume percent, which, for this soil, corresponds to a soil water tension of approximately 0.15 MPa. Three weeks were allowed for equilibration before planting the cultivars and covering the soil surface with ground corn stover at rates equivalent to 0, 5, or 10 Mg ha^{-1}. Water use was measured by weighing the pots daily and adding water to the soil surface to compensate for evapotranspiration. Shoot growth was measured by clipping the wheat plants twice at a height of 25 mm. Root growth was measured at the end of the study after washing the soil through a sieve with water. Plant tissue was dried at 65°C to determine dry matter production.

Statistical analyses of data from Studies I, II, III, IV, and VIII were made using a split-plot experimental design (18). Data from Studies V, VI, and VII were analyzed using a stripped split-split plot experimental design. Data from the greenhouse experiment (Study IX) were analyzed using a randomized complete block design. Least significant difference (LSD) values were calculated only if F values were significant at $P = 0.10$ or lower.

RESULTS AND DISCUSSION

Tillage system effects on wheat grain yield when averaged across N rates in Studies I, II, III, and IV are summarized in Table 2. Moldboard plowing consist-

[3] Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA or the South Carolina Agric. Exp. Stn., and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

Table 2. Wheat yields as affected by tillage system when averaged across N rates on Dothan or Ardilla loamy sand in 1983, 1984, or 1985.

Tillage system	Study I	Study II	Study III	Study IV
	Mg ha^{-1}			
Disking	2.13	2.48	2.42	2.04
Chisel plow	2.32	3.01	2.69	2.25
Moldboard plow	2.55	3.10	2.93	2.32
LSD (0.10)	0.26	0.53	NS	0.21
CV (%)	7.4	16.8	25.9	12.3

Table 3. Wheat yields as affected by tillage system when averaged across N rates on Norfolk loamy sand in 1983, 1984, or 1985.

Tillage system	Study V	Study VI	Study VII	Study VIII
	Mg ha^{-1}			
No tillage	1.90	3.18	2.41	1.87
Disking	2.36	3.45	2.41	2.33
Chisel plow	--	--	--	2.48
Moldboard plow	--	--	--	3.09
LSD (0.10)	0.11	NS	NS	0.34
CV (%)	10.0	22.3	34.3	21.5

ently gave the highest grain yield. With the exception of Study III, yield differences between plowing and disking were always statistically significant at $P = 0.10$. Yield response to chisel plowing was intermediate, presumably reflecting a similar tillage depth (200–250 mm) but a less complete loosening or mixing of the Ap horizon than with moldboard plowing. Interactions between tillage system and N rate were not significant at $P = 0.10$, except for Study III when lodging was increased by high rainfall. The highest grain yields in that study were achieved with moldboard plowing and a total of only 80 kg ha^{-1} N.

Moldboard plowing also resulted in the highest grain yield when averaged across four cultivars in Study VIII (Table 3). The positive yield response to moldboard plowing, which was observed in these five studies, was also found on Appalachian Piedmont soils (13,19), Florida Coastal Plain soils (D.A. Wright, 1985, personal communication), and in the Alabama Coastal Plain (16). Similar results (12) were also reported for wheat production on loamy sand in Australia. Disruption of compacted tillage/traffic pans (13) and improved aeration (3) are probably the two most important reasons for higher wheat yields with chisel or moldboard plowing than with disking, but increased S availability may also be a contributing factor. In many Coastal Plain soils, S, K, and B accumulate in the Bt horizon and are positionally unavailable if plant roots can not penetrate compacted tillage/traffic hardpans or genetic E horizons. Increased S concentrations in the plant (1.8, 2.0, or 2.5 g S kg^{-1} dry matter for disk, chisel plow, or moldboard plow treatments, respectively) at FGS 7.0 suggest that improved plant nutrition was a factor contributing to higher grain yields for the plowed treatment in Study I. The N/S ratios for that study averaged 14.5, 12.6, and 10.8 for disk, chisel, and moldboard treatments, respectively, and also suggests that plowing 200 to 250 mm deep improved nutrient balance when compared to disking 100 mm deep.

No-till wheat production was evaluated on Norfolk loamy sand in Studies V, VI, VII, and VIII. With the exception of Study VIII, there were no significant interactions at $P = 0.10$ or lower. Comparisons between no-till and disking for seedbed preparation showed significantly lower no-till yields in Studies V and VIII, but no differences in Studies VI and VII (Table 3). Total N applications in the former studies were 107 and 90 kg ha^{-1}, respectively, while in Studies VI and VII, the average N fertilization rate was 150 kg ha^{-1}. This indicates that no-till wheat on Norfolk type soils will require more N than when conventional tillage practices are used, and is consistent with previous results (10, p. 441–455). Measurements of residual N are usually not made in this region because organic matter is low (<10 g kg^{-1}) and leaching is high. However, measurements after corn harvest in 1985 at the site of Studies V, VI, and VII showed a total Kjeldahl N in the upper 0.15 m of only 250 to 400 mg kg^{-1} and a total NO_3 accumulation of 25 mg kg^{-1} in the upper 1.2 m of soil (T.A. Matheny, unpublished data). The effective rooting depth for wheat in these soils was not too deep because tensiometer data collected for Studies V, VI, and VII (not presented) showed very little water extraction from below 0.45 m until grain fill. This suggests that a wheat crop in this region will be primarily dependent on fertilizer N rather than residual soil N.

Tillage system effects on the number and weight of unthrashed wheat heads per square meter were measured in Studies IV, VI, VII, and VIII (Table 4). There were no differences or interactions in Studies VI and VII, which included irrigated and nonirrigated blocks but compared only no-till and disk treatments. In Studies IV and VIII, which were nonirrigated, deeper tillage (200–250 mm) associated with moldboard or chisel plowing, or both, significantly increased head number and weight when compared to preparing the seedbed by disking at a depth of approximately 100

Table 4. Tillage system effects on the number and unthrashed weight of wheat heads per square meter in Studeis IV, VI, VII, and VIII.

Tillage system	IV no.	IV g	VI no.	VI g	VII no.	VII g	VIII no.	VIII g
No tillage	--	--	402	818	412	381	374	274
Disking	508	668	397	869	416	404	350	299
Chisel plow	494	597	--	--	--	--	400	368
Moldboard plow	644	850	--	--	--	--	392	430
LSD (0.10)	65	93	NS	NS	NS	NS	32	38
CV (%)	14.8	16.6	36.8	27.2	30.4	45.0	13.1	17.1

Table 5. Tillage × cultivar interaction effects on grain yield of wheat grown on Norfolk loamy sand near Florence, SC in 1985.

Tillage system	Coker 916	Coker 983	HW3021	HW3022
	Mg ha^{-1}			
No tillage	1.18	1.79	2.40	2.13
Disking	1.62	2.26	2.84	2.60
Chisel plow	1.76	2.56	3.00	2.59
Moldboard plow	2.81	2.89	3.60	3.07
Interaction LSD (0.10)		0.32		
CV (%)		9.1		

Table 6. Effects of surface-applied corn residue on stand establishment, water use, shoot weight, and root weight for selected wheat cultivars in a greenhouse experiment.

Residue rate	Plant count	Water use	Shoot weight	Root weight
Mg ha^{-1}	no. pot^{-1}	mL day^{-1}	g pot^{-1}	
0	29.4	152	3.56	1.79
5	30.5	145	3.58	1.95
10	29.7	134	3.41	1.75
LSD (0.10)	NS	4	NS	NS
CV (%)	6.5	4.7	7.7	26.1

Table 7. Water use, shoot weight, and root weight for selected wheat cultivars grown for 33 days under greenhouse conditions.

Cultivar	Water use	Shoot weight	Root weight
	mL day^{-1}	g plant^{-1}	
Coker 916	139	3.27	1.60
Coker 983	141	3.18	1.60
Hybrex 3021	146	3.94	1.95
Hybrex 3022	148	3.78	2.17
LSD (0.10)	5	0.19	0.33
CV (%)	4.7	7.7	26.1

mm. This response to deeper tillage presumably occurred in Studies IV and VIII because rainfall in 1985 was lower than that in 1983 or 1984 (Table 1). The irrigation response in 1985 (Study VII) emphasizes how dry the growing season was because yields were increased from 1.67 to 3.14 Mg ha^{-1}. In 1983 and 1984 (Studies V and VI), however, supplemental irrigation had no significant effect on wheat yield at $P = 0.10$ because rainfall was not limiting for wheat production.

The tillage system × cultivar interaction in Study VIII was significant at $P = 0.10$ because one cultivar (HW3022) yielded more with disking than with chisel plowing (Table 5). All four cultivars, however, produced the highest grain yields with moldboard plowing and the lowest with no-till.

A consistent problem for all no-till wheat treatments was an erratic stand establishment. The effect of this on grain yield measurements was minimized by selecting uniform strips for harvest, but on a production scale, nonuniform stands will limit acceptance of no-till techniques. To determine if phytotoxic substances from the corn residue were causing the stand establishment problem, Study IX was conducted using the same four wheat cultivars that were used in field Study VIII. Interactions between cultivar and surface residue treatments were not statistically significant, so only main effects are presented. Applying corn residue to the soil surface had no significant effect on seedling emergence, shoot weight, or root weight, but it did significantly reduce the amount of evaporation and thus daily water use (Table 6). Among the four cultivars, shoot and root growth were greatest for the hybrids HW3021 and HW3022 (Table 7).

Potential water conservation aspects of a residue-covered seedbed were evident, but more importantly, Study IX demonstrated that stand establishment problems in the no-till field studies were not caused by phytotoxic substances. The most probable cause, therefore, was poor soil-seed contact associated with the use of a KMC Uni-drill for planting wheat into corn residue. This suggests that for a successful no-till wheat following corn, a different type of no-till drill will be required.

Table 8. Mean grain yield response by wheat to N on selected loamy sands in the South Carolina Coastal Plain.

Study	Soil series	Harvest year	Fertilization rate (kg ha^{-1}) 67	90	100	112	134	168	200	235	LSD (0.10)	CV %
I	Dothan	1983	2.08	2.44	2.48	--	--	--	--	--	0.14	8.7
II	Ardilla	1983	2.41	2.93	3.25	--	--	--	--	--	0.24	11.7
III	Ardilla	1984	--	2.49	--	2.65	2.89	--	--	--	0.21	11.0
IV	Ardilla	1985	--	2.15	--	2.34	2.12	--	--	--	NS	13.8
VI	Norfolk	1984	2.48	--	3.10	--	3.16	3.44	3.90	3.80	0.28	16.0
VII	Norfolk	1985	2.08	--	2.32	--	2.54	2.39	2.59	2.52	0.16	12.7

In six of the eight field experiments (I, II, III, IV, VI, and VII), N was included as a variable. This occurred because changes in tillage were known to cause differences in microbial populations, which change the availability of N in wheat and corn production systems (10, p. 441–455). Grain yield response to N was significant at $P = 0.10$ in all but Study IV (Table 8), which was the only study with a significant tillage × N interaction (Table 9). The interaction occurred because high seasonal rainfall (Table 1) caused lodging in moldboard plow treatments if total N exceeded 90 kg ha^{-1}. In the studies where significant N rate differences were found, yields at low N rates were lower than those at high N rates (Table 8). Overall, these studies suggest that for growing wheat with conventional tillage in the Coastal Plains, a total N rate of approximately 100 kg ha^{-1} will be adequate. For no-till production, N rates may have to be increased by 25 to 50%, but further research needs to be conducted to determine optimum rates for those practices in this region.

Head weight for the low N treatment (34-34) averaged 700 g m^{-2} in Study VI and was significantly lower [LSD(0.05) = 115] than for the other five N treatments, which averaged 880, 830, 865, 855, and 925 g m^{-2}, respectively. There were no significant N effects on head number or weight in Studies IV or VII.

The results of eight field studies and one greenhouse experiment show that moldboard or chisel plowing are the optimum tillage systems for wheat production on southeastern Coastal Plain soils. Deeper (200–250 mm) tillage systems apparently disrupt compacted tillage/traffic hardpans and probably improve aeration more than disking 100 mm deep or planting no-till wheat. The greenhouse study suggests that nonuniform stand establishment in no-till treatments was caused by poor soil-seed contact rather than phytotoxic effects of the corn residue. In the future, no-till wheat research should utilize another type of drill for planting wheat into chopped corn stover. No-till wheat appears to need more fertilizer N than wheat planted into a conventional seedbed on Coastal Plain soils, but additional

Table 9. Tillage × N interaction effect on grain yield of wheat in Study IV conducted on Ardilla loamy sand near Blackville, SC, in 1984.

Tillage system	N Fertilization rate (kg ha^{-1}) 90	112	134
		Mg ha^{-1}	
Disking	2.12	2.24	2.89
Chisel plow	2.38	2.81	2.87
Moldboard plow	2.98	2.91	2.89
Interaction LSD (0.10)		0.36	
CV (%)		11.0	

research with uniform no-till stands will be needed to quantify the rates. Finally, supplemental irrigation increased wheat yield in only one of three studies. This indicates that seasonal rainfall is generally adequate for producing wheat at current yield levels in the southeastern Coastal Plains.

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